Stochastic Cooling code

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Stochastic Cooling

- Described by Fokker Planck Equation

$$\frac{\partial \psi}{\partial t} = -\frac{\partial}{\partial E}[F(E)\psi - D(E)\frac{\partial \psi}{\partial E}]$$

  - *F(E)* cooling term: *coherent self force*
  - *D(E)* diffusion terms:

    electronic noise, IBS, heating from other particles

it is all about describing the terms!!!

Available Code

- Longitudinal and Betatron cooling
  Time integration of FPE
- Fortran and C++
  for the longitudinal code, have checked numerical equivalence of two implementations, good to 1 part in 10^8

Fortran inherited from J. Marriner (originally from S. van der Meer), see Pbar 498 for detailed description

C++ implementation by me

algorithm as developed by van der Meer and Marriner to handle the time integration and stability

S. van der Meer, "A different formulation of the longitudinal and transverse beam response", CERN/PS/AA/80-4, (1980), unpublished

Longitudinal Simulation

- Describe ACCELERATOR

  parameters of the machine

- Describe FREQUENCY_BAND

  over what frequency does system function

  sample subset of harmonics (2GHz BW → 6330 Harmonics)

- Describe SYSTEM_ELEMENTS

  pickups, kickers, electronics over frequency band of interest

  - gain (magnitude and phase) *defines cooling terms*
  - feedback component *enters diffusion terms*

Forcing Term *F(E)*

- Calculation of *F(E)*:

$$F(E) \sim \mathrm{Re}[\frac{\mathrm{Transfer\ \ Function}}{1-\mathrm{FG}}]$$

  - Transfer Function
    - (pickup response × electronic gain × kicker response)
  - Feedback component FG
    - electronic gain × (pickup×kicker feedback)

Diffusion Term *D(E)*

- Three Components to *D(E)*
  - Heating from other particles: D_2

    $$\sim \left|\frac{\text{Transfer Function}}{1-\text{FG}}\right|^2 \times \text{Mixing Factor}$$

  - Electronic Noise: D_1

    $$\frac{\text{kTB (Electronic Gain)}^2}{|1-\text{FG}|^2}$$

  - Other: D_0
    - Scale by $\Psi(E)$
    - IBS -- not too important in Accumulator/Debuncher longitudinal
    - Vacuum term -- not implemented but easy to put in

Integration

- From *F(E)* and *D(E)*
  - calculate FLUX(from *E* to *E*+δ*E*) per time step

$$Flux = (D_0(E) + D_1(E) + D_2(E) \times \Psi(E))\frac{\Delta\Psi}{\delta E} - F(E) \times \Psi(E)$$

Other Heating Terms

Amplifier Noise Heating

Other Particle Heating

Cooling

  - redistribute density

Working on....

2 Dimensional Cooling?

Longitudinal code & Betatron code

for each longitudinal bin, transverse distribution also

100 msec longitudinal cooling, then do 100 msec betatron cooling

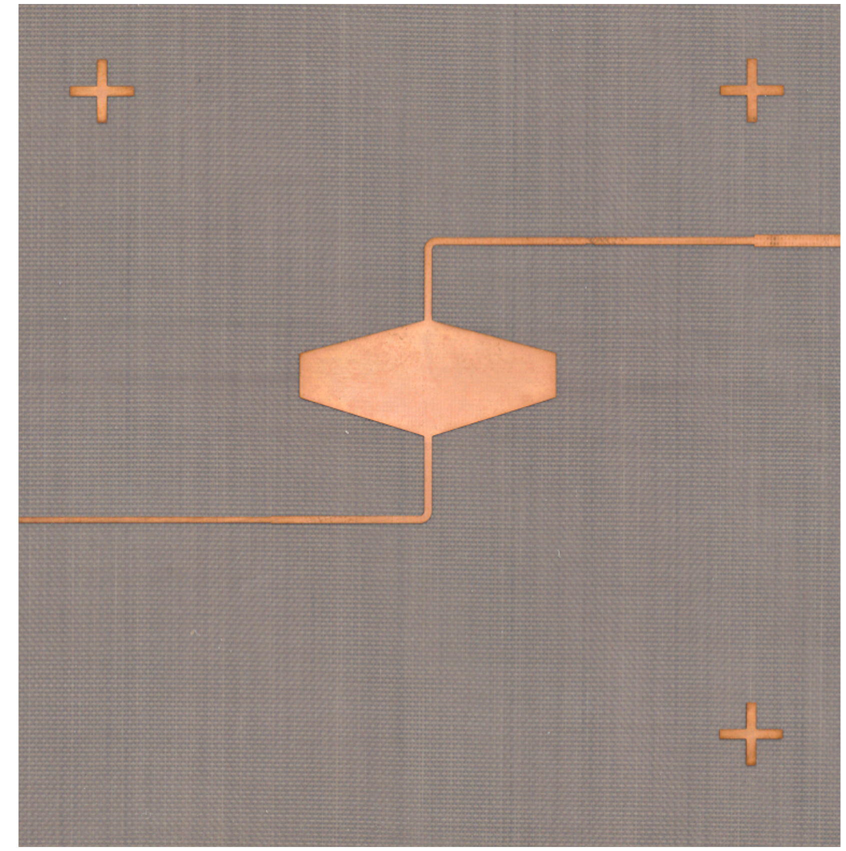
betatron cooling depends on longitudinal distribution while longitudinal is independent of betatron distribution (up to IBS contributions....)

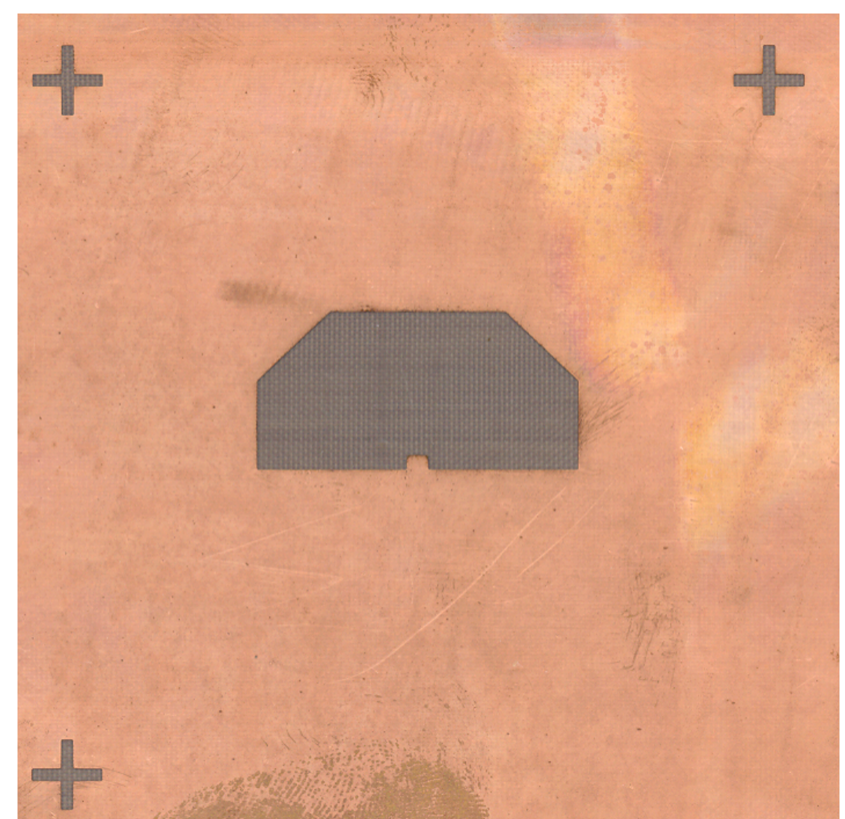
Implementations -- design tool

- Accumulator Momentum
  - Tev I
  - Run II
  - Run II upgrades
- Debuncher Momentum: 4 band system
- Debuncher Transverse: 4 band system
- Recycler Momentum & Transverse Design

Modelling

- Pickups: in 1997 tests in Accumulator (4 designs)
  - varying physical parameters of the loop
- Compare to model:
  - integrate image charge to calculate response
  - function of aperture and loop shape
  - gain and phase behavior well predicted





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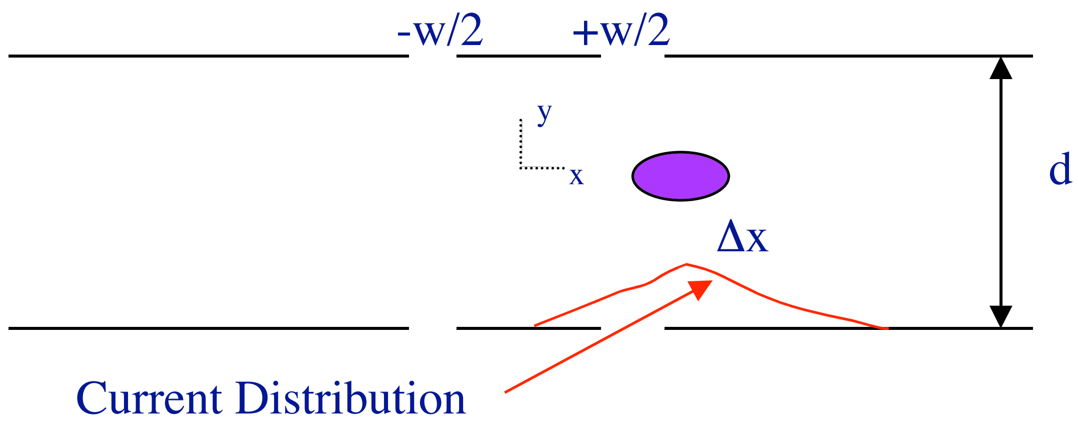

$$I = \frac{I_{beam}}{\pi}\{\arctan[\sinh(\frac{\pi}{d}(\Delta x + \frac{w}{2}))] - \arctan[\sinh(\frac{\pi}{d}(\Delta x + \frac{w}{2}))]\}$$

$$\approx \frac{I_{beam}}{\pi}\exp(-\frac{\pi\Delta x}{d})\text{for large }\Delta x$$

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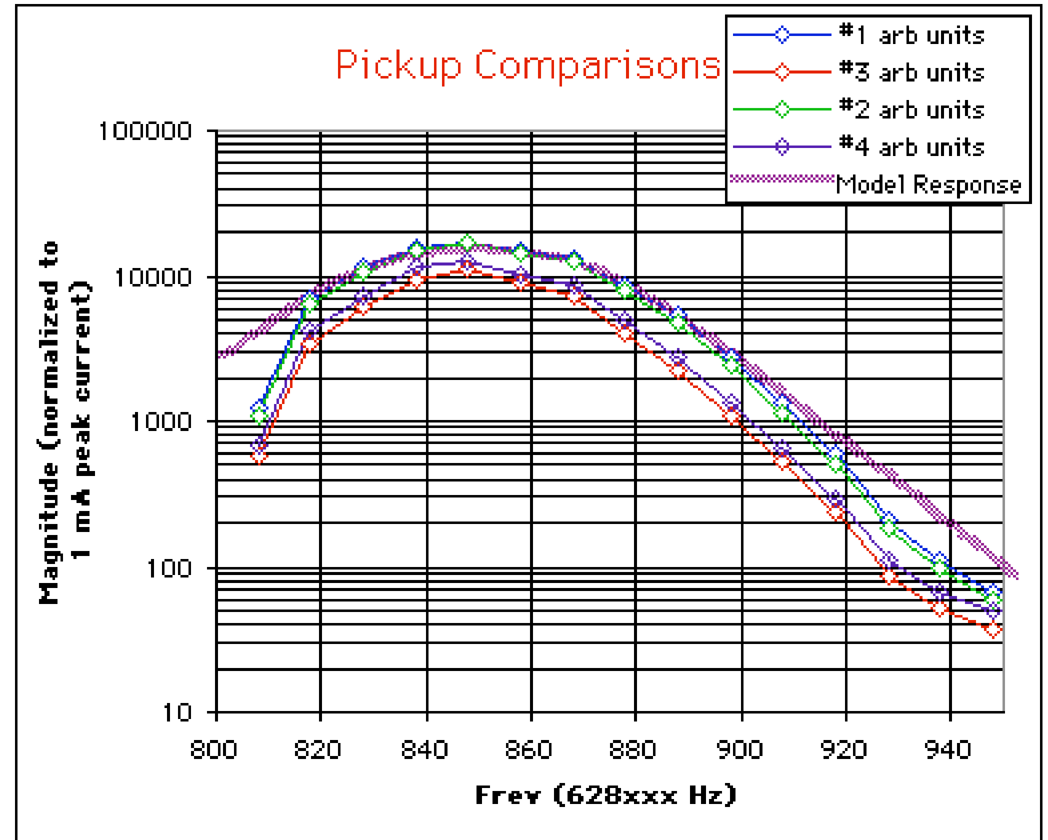
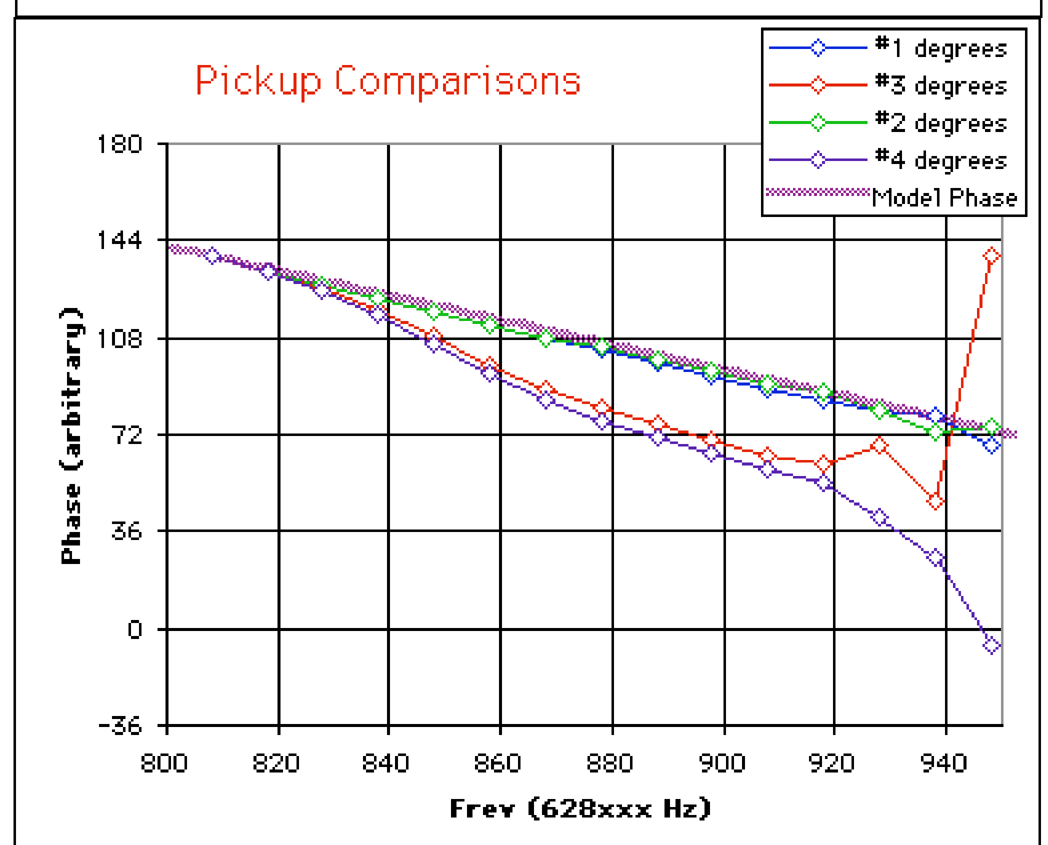
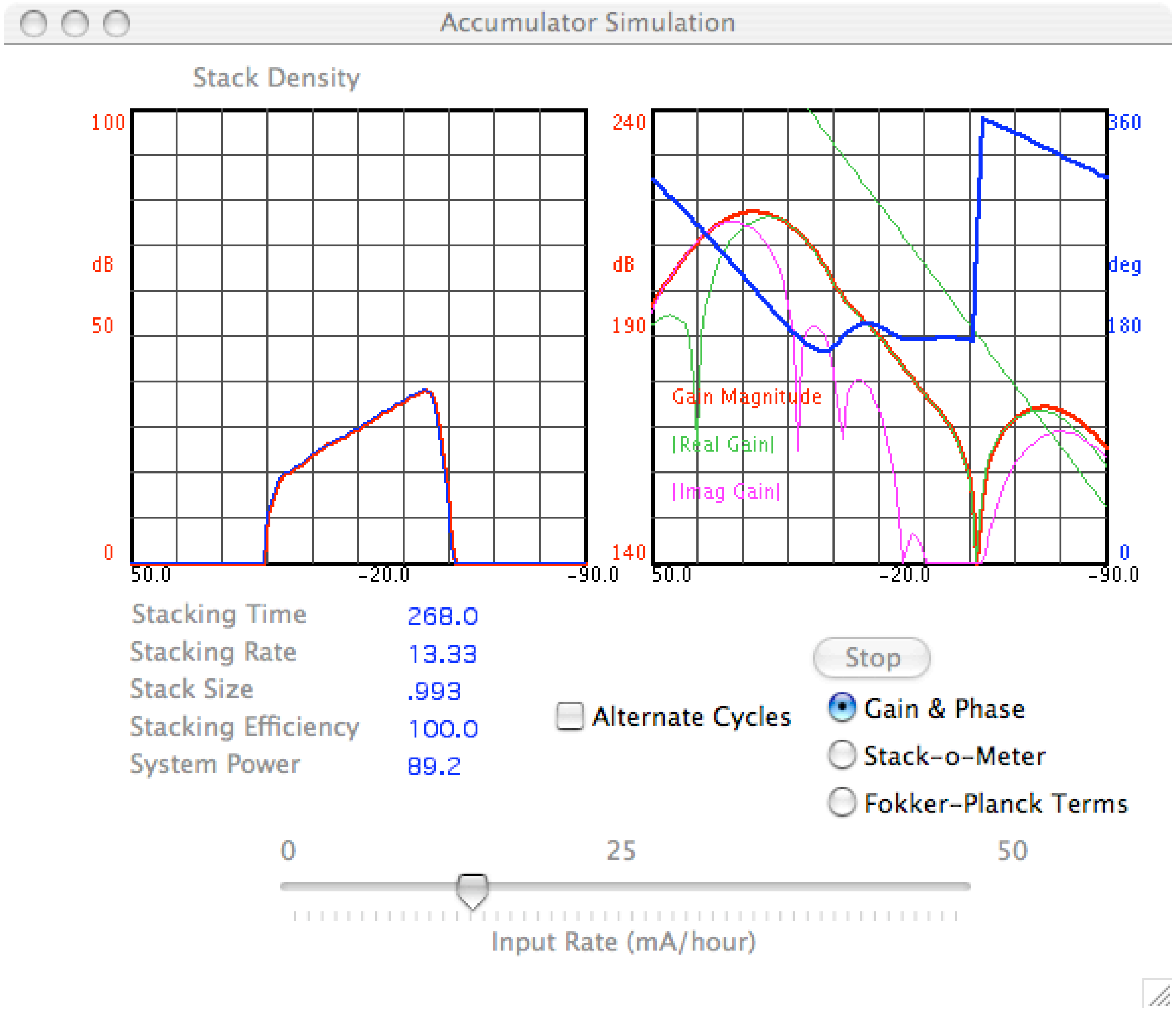




Implementation



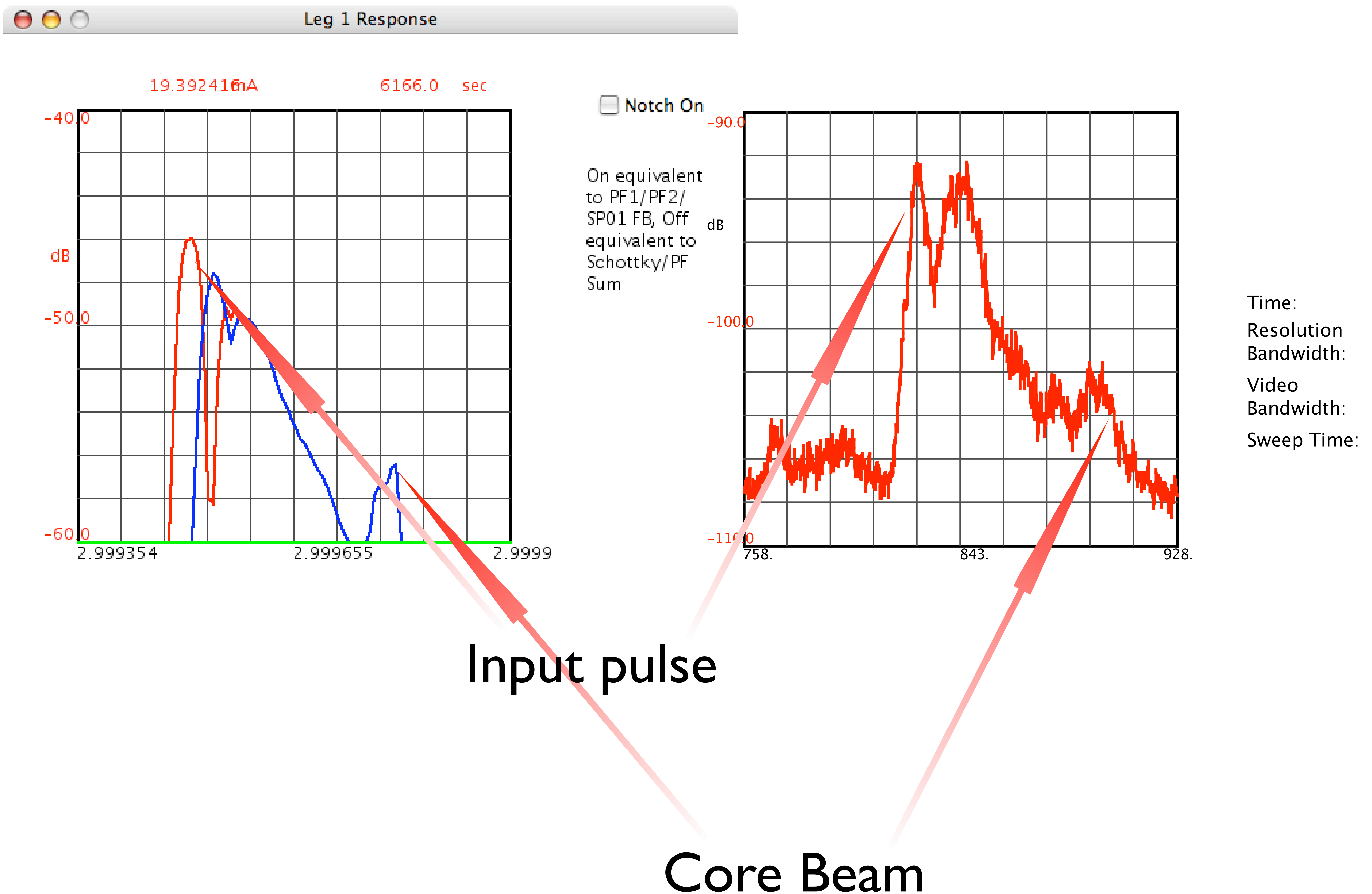
Features available

- Fokker Planck Terms:
  - *F(E),* heating from other particles, noise, Flux
  - Dynamically at each step (or at particular steps in the integration)
- Performance History: Stack-o-meter
- Schottky spectra at various points
  - mimic the places we can look at them with real system
- Stability Terms:

  as feedback is an important element in stochastic cooling

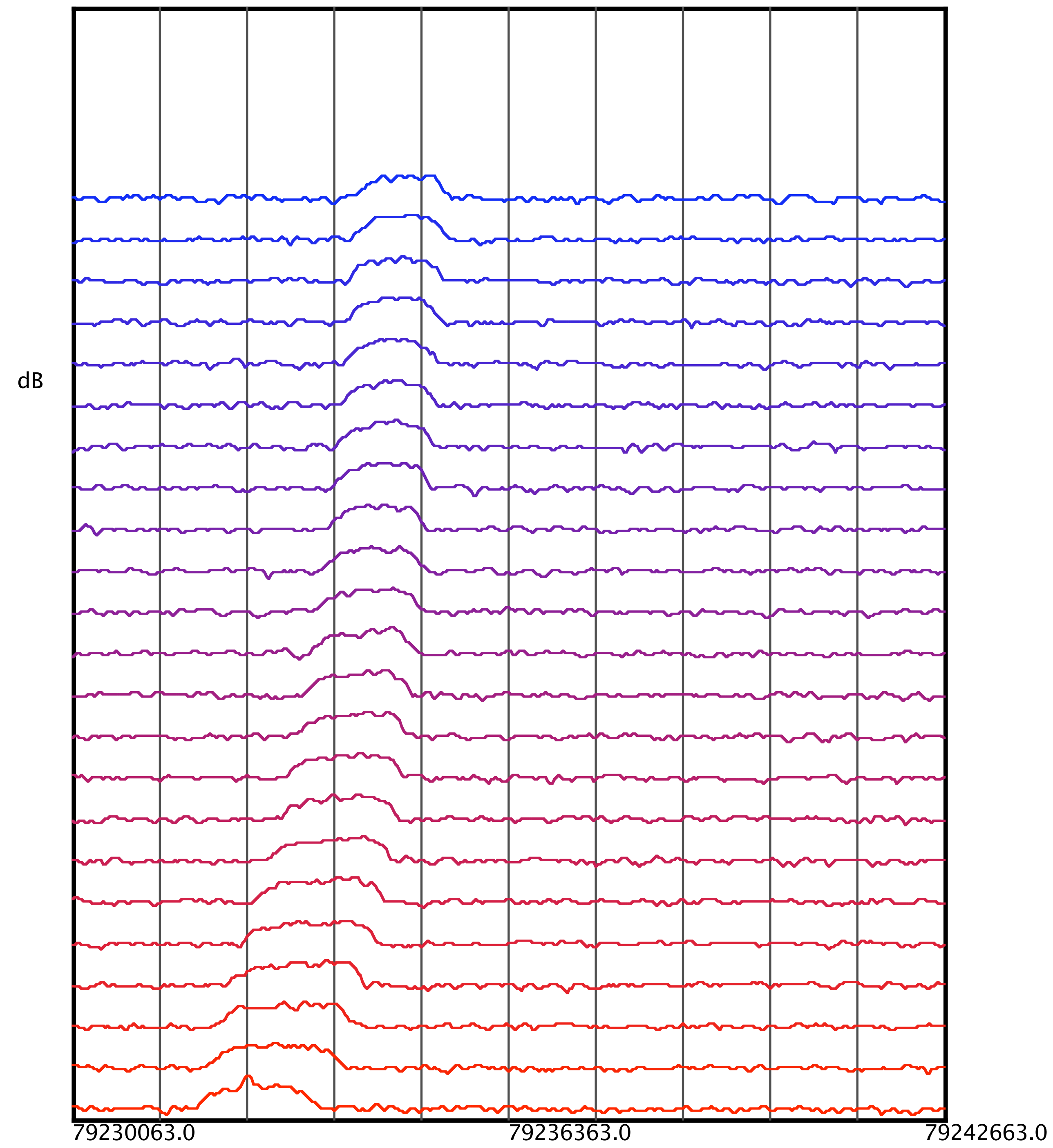
Show Program and some features!

Leg 1 Schottky Response



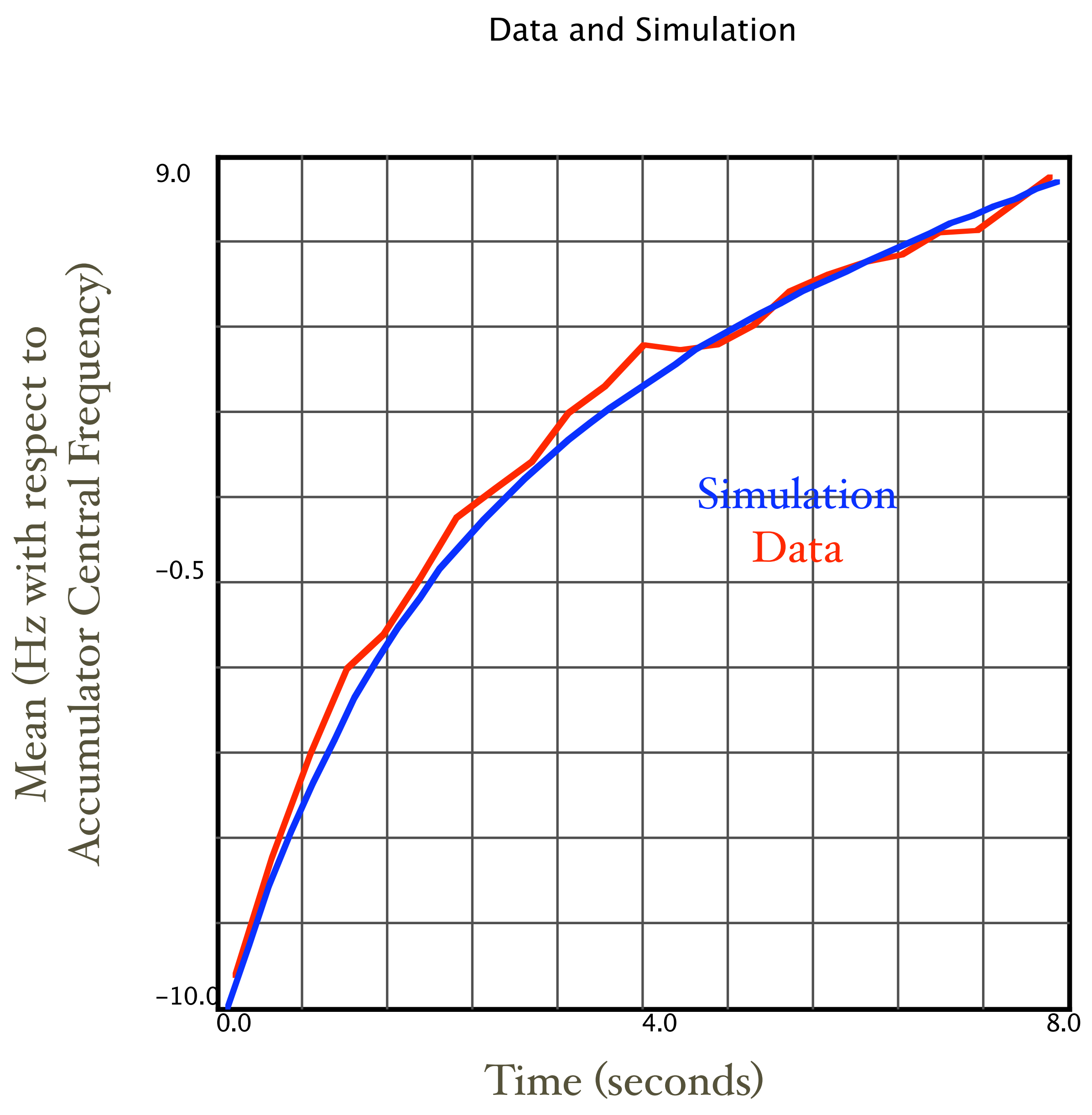
Simulation Tests

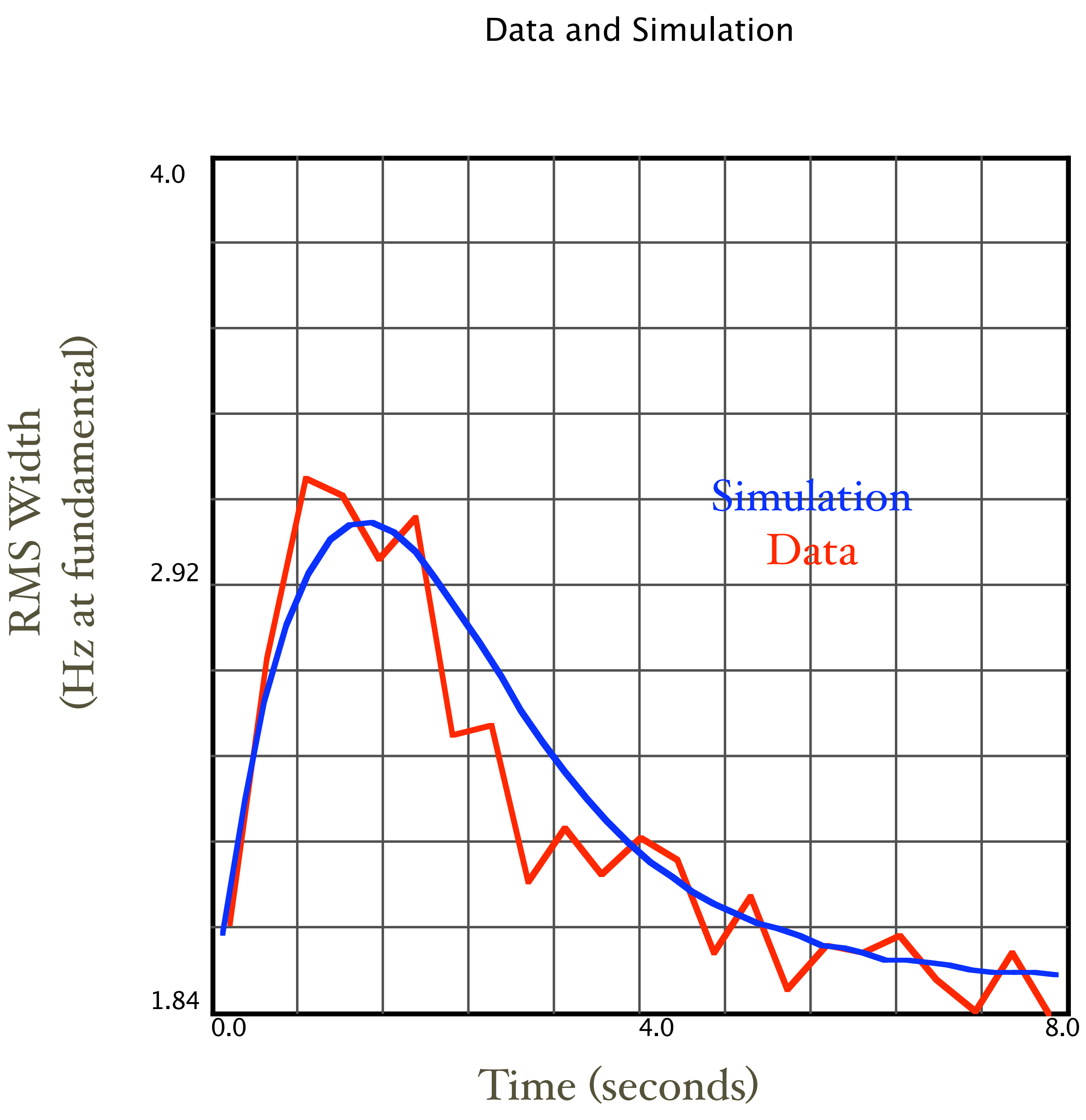
- Single Pulses into the Accumulator
- 79 MHz Schottky signal into Vector Signal Analyzer
- Subtract Noise Floor, Calculate MEAN and RMS of pulse



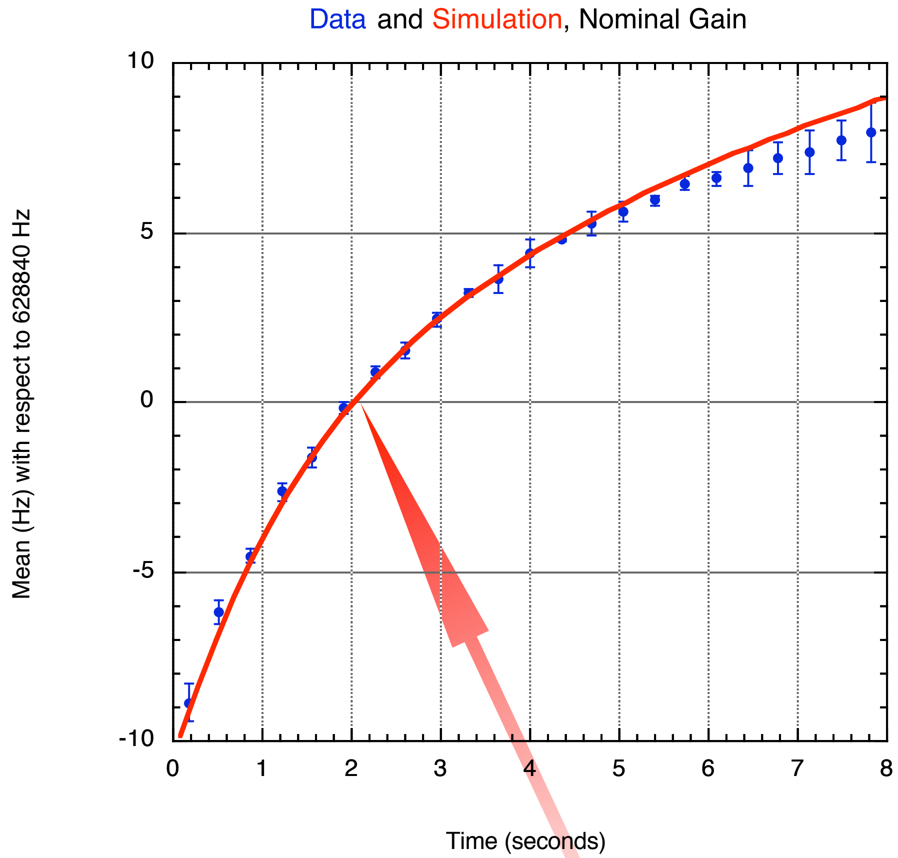
8 seconds of data

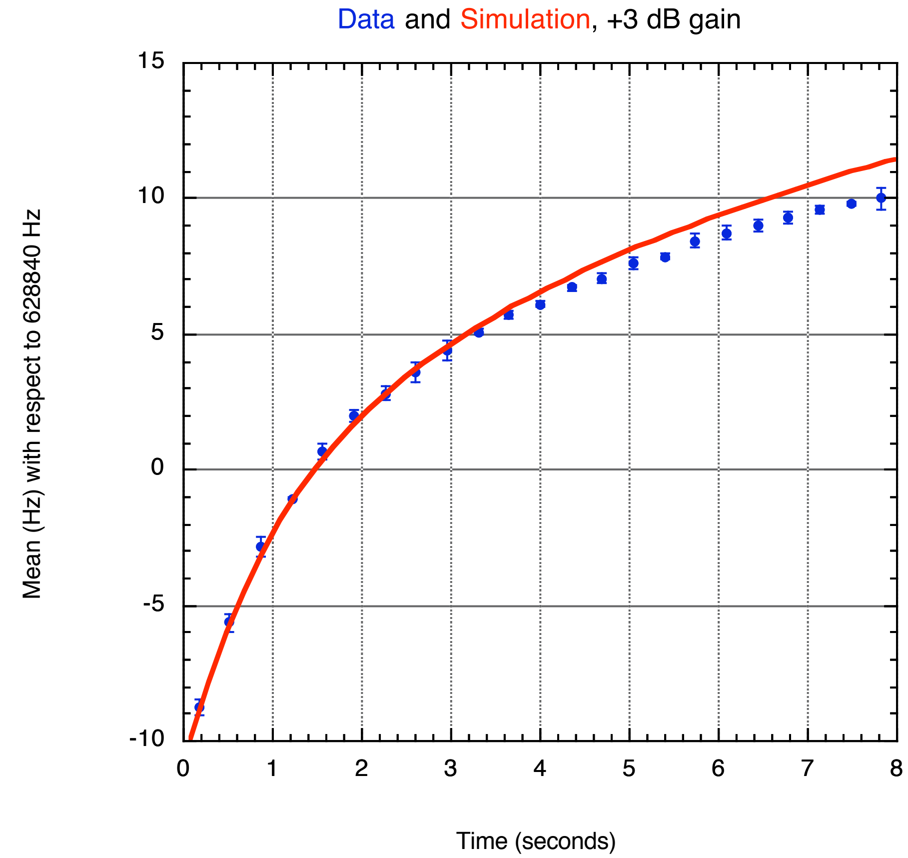
Comparing nominal settings

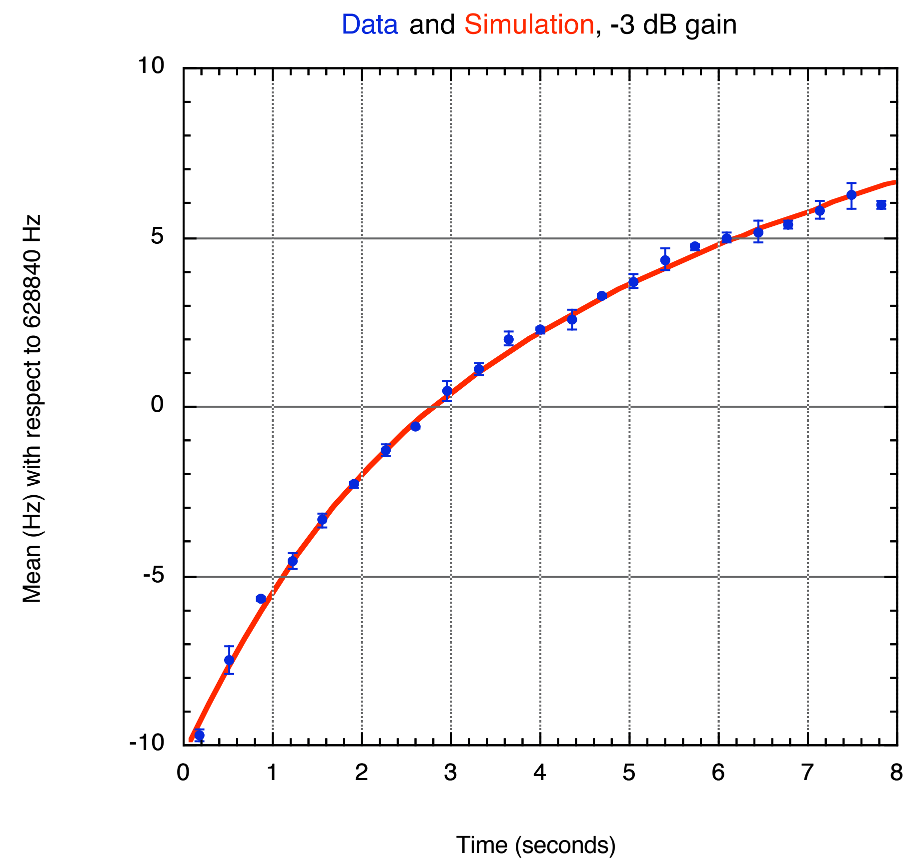




Pulse Evolution Measures







Adjusted gain in simulation to match Data over first 3 seconds mismatch above 6 Hz - different slope in simulation than Accumulator (supported by recent measurements)

Debuncher Cooling

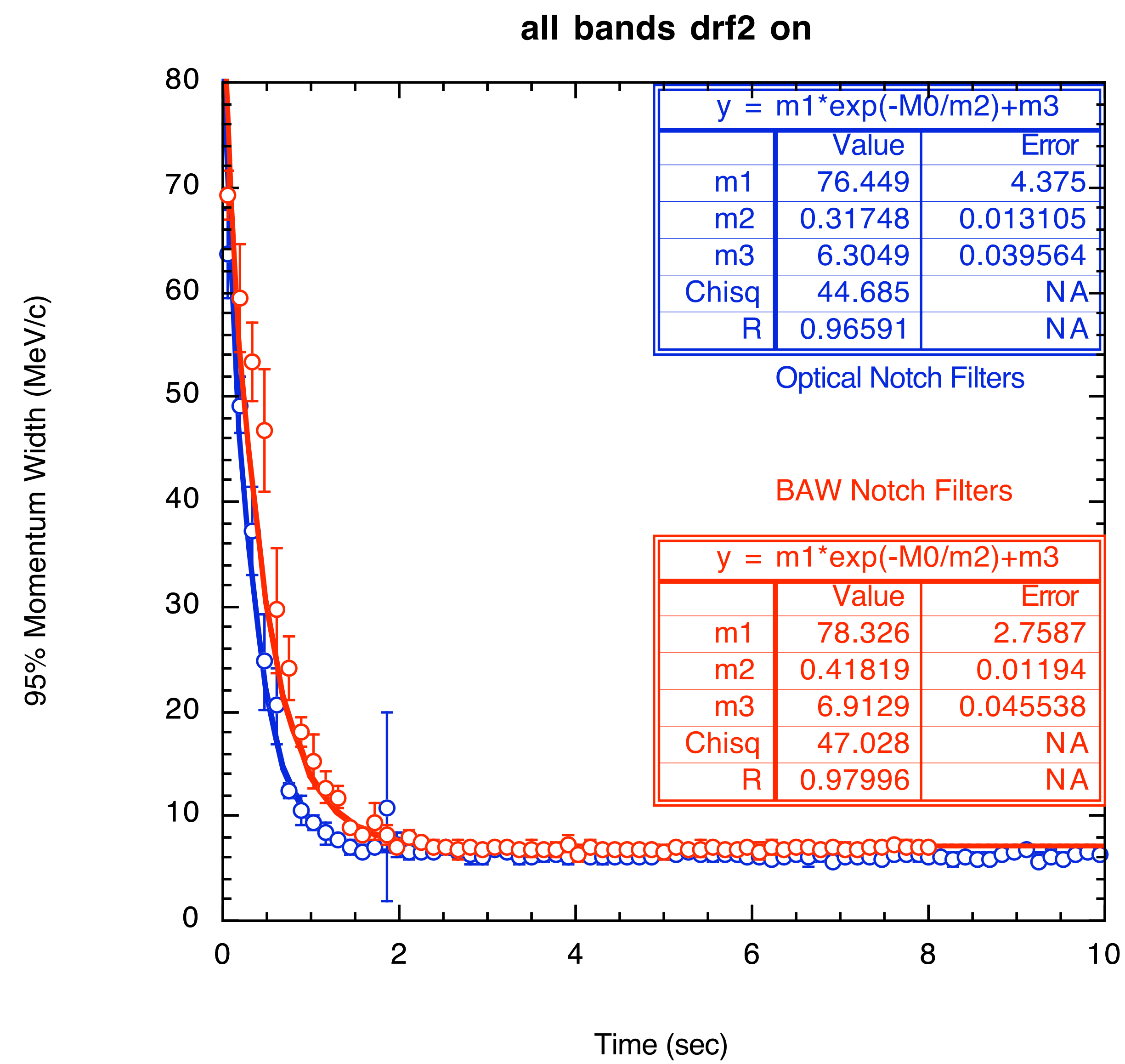
5.2 GHz Schottky into VSA

Measure 95% width vs time

Have not been able to duplicate with simulation

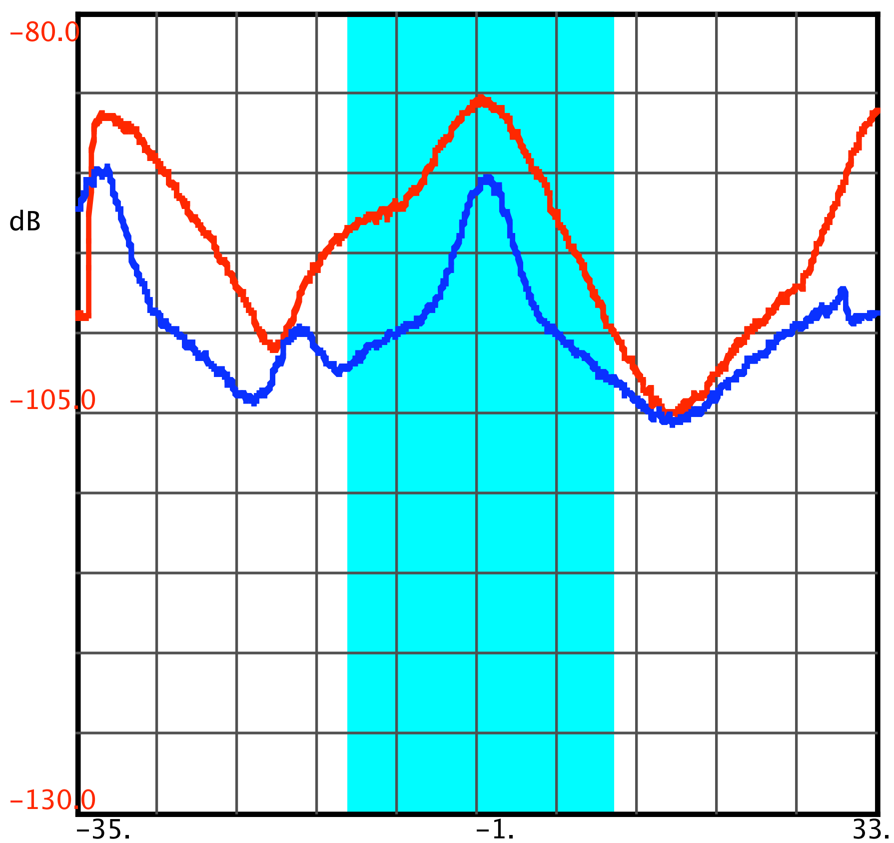
- set gain to match noise power, factor of 5 slower!

- Missing something in description of system?



Debuncher Transverse

- 5.2 GHz Schottky, Spectrum Analyzer in 0 span mode: integrate power in betatron sideband
- Trigger on injection, sweep gives relative emittance
- Compare model and Mcginnis measurements from summer 04



Time:	not known
Resolution Bandwidth:	not known
Video Bandwidth:	not known
Sweep Time:	not known

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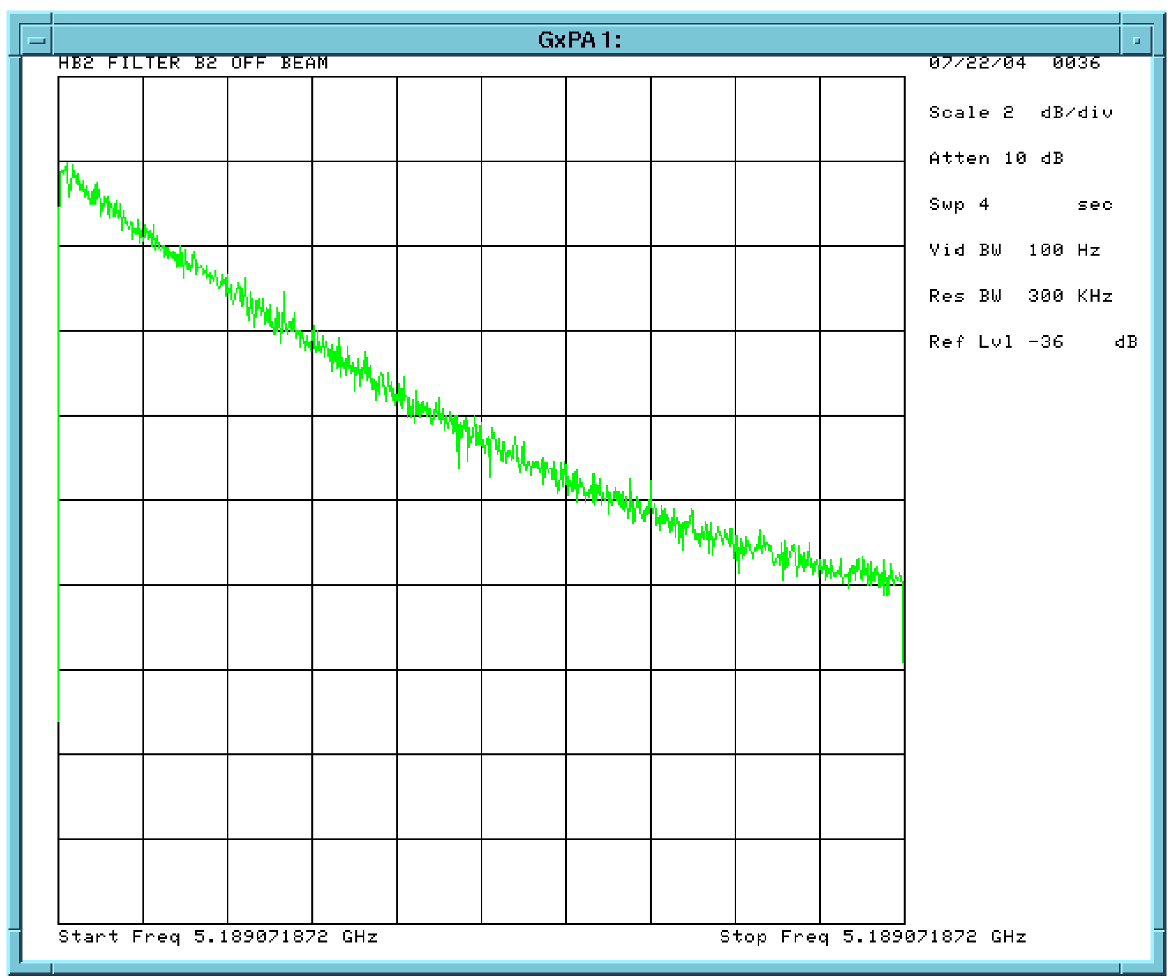

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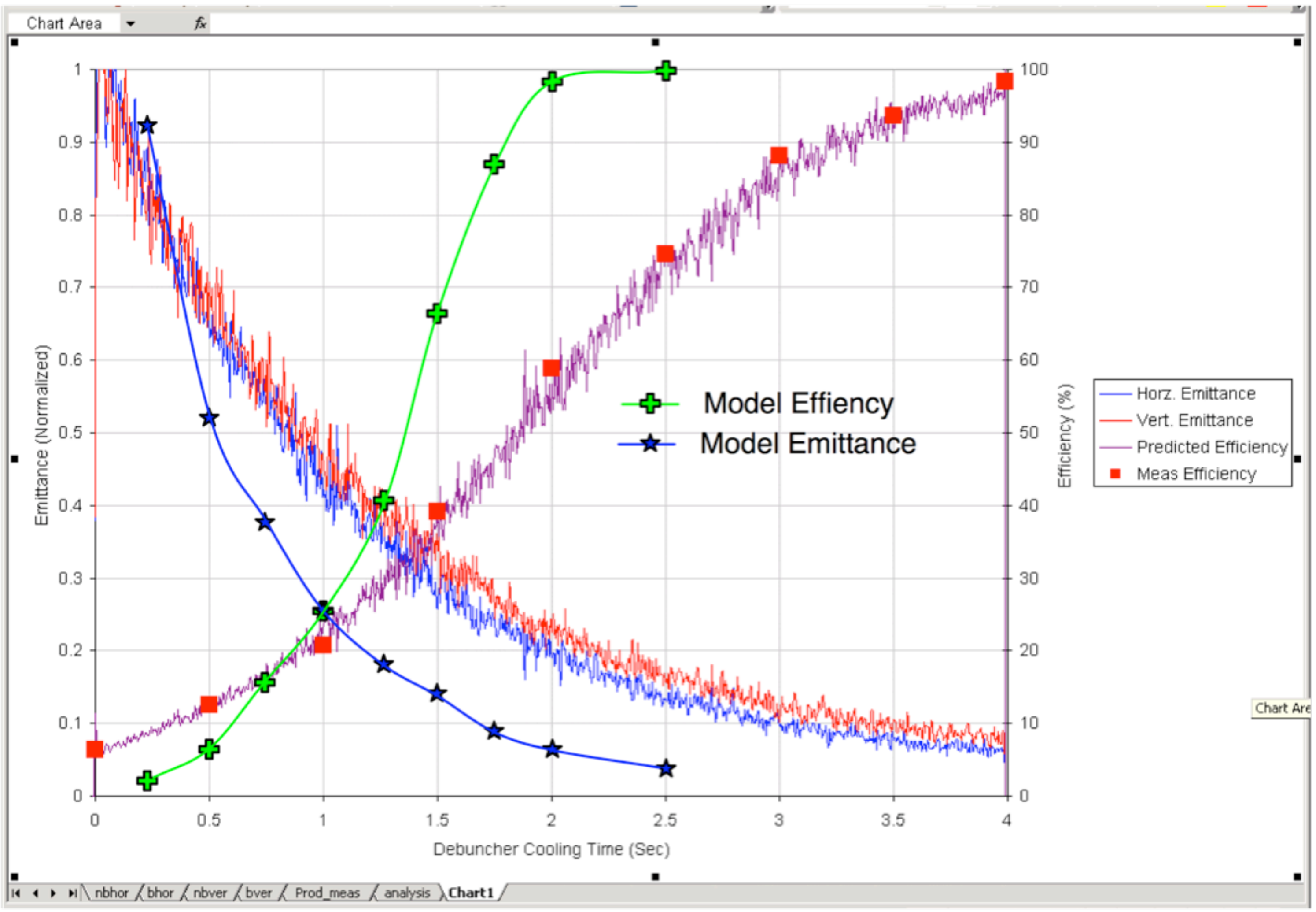

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Have some work to do on
Debuncher modelling

investigating pickup and kicker response
input distributions